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# Employing ubiquitous computing devices and technologies in the higher education classroom of the future

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## Abstract

This paper explores the utilization of “pervasive” or “ubiquitous” computing devices and technologies in the higher education classroom of the future. Firstly, a survey on the characteristics and the applications of today’s ubiquitous computing devices is presented, along with a questioning on the level of their ubiquity. Such devices include smartphones, PDAs, Tablet PCs, iPods, as well as reading appliances, Pad-type appliances, interactive whiteboards and telepresence boards. Multiple network connections such as cellular, Wi-Fi, Bluetooth, and NFC, provide long-, medium-, or short-range wireless communication for different mobile devices. In the following, we investigate how innovative ubiquitous computing devices and technologies can be employed in education learning environments to enhance active learning by anyone, anytime and anywhere, as well as to enable blended learning, individually and collaboratively. A representative use case is presented to reveal the new possibilities for learning that a classroom equipped with ubiquitous computing devices can offer to students. Interviews with experts helped us to give proposals on the utilization of the advantages of ubiquitous computing technology in the higher education classroom of the future.

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## 1. Introduction

Ubiquitous computing is a term referred to Weiser’s vision [1] of a world where invisible computers would support people in everyday activities, offering boundless access to information resources anytime and anywhere.

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In an educational environment, teachers and students can take advantage of new trends in ubiquitous computing, employing ubiquitous devices and technologies in the classroom. Actually, young people carry mobile devices anywhere and anytime and enjoy playing with new gadgets [2]. Educators and curriculum developers need to acknowledge this reality and adopt “mobile 21st-century tools for 21st-century learners” [3].

An electronic learning (e-learning) environment is characterized by the dissemination of knowledge over the Internet. In e-learning, desktop or laptops computers, software tools such as e-tutoring and self-assessment, and communication applications such as chat, forums and video calls can be used to support distance learning. A mobile learning (m-learning) environment is a learning environment supported by mobile devices such as WebPads, Ultra-Mobile PCs, Tablet PCs, Personal Digital Assistants (PDAs) and smartphones. These devices can connect to Internet through wireless communication technologies. M-learning is considered either as a subset of e-learning [4] or an extension of e-learning [5]. M-learning is not just e-learning with mobile devices. Information is accessed from anyplace (spatial aspect of mobility), at anytime (temporal aspect of mobility) and also by anyone (individually and collaboratively) [6].

After the introduction of e-learning and m-learning, the assimilation of ubiquitous computing in education has led to the emergence of ubiquitous learning (u-learning). U-learning environments integrate not only m-learning into e-learning environments [7], but also pervasive learning environments that utilize invisible computers such as wearable computers, or sensors and computers embedded in objects [8]. While m-learning environments focus on mobility, pervasive learning environments focus on embeddedness. Therefore, u-learning integrates m-learning and pervasive learning to a high level of mobility and a high level of embeddedness [9]. U-learning environments are supported by mobile and ubiquitous computing technologies including mobile devices, embedded computer devices such as GPS, RFID tags and sensors, pads, and badges, as well as wireless sensor networks. Hwang et al. [10] clarified the confusion of the term “u-learning” and the related terms “m-learning”, “learning with u-computing technology”, and “context-aware u-learning”. In particular, the definition of u-learning as “anywhere and anytime learning” is broader than m-learning, which demands mobile devices and wireless communication. Then, “learning with u-computing technology” is a special case of m-learning, since it emphasizes not only the usage of wireless communication but also sensor technology. Finally, “context-aware u-learning” that employs mobile devices, wireless communications and sensor technologies in learning activities, can be considered a special case of learning with u-computing technology. Therefore, a u-learning environment is considered a superset of the other three types of environments.

The context-aware feature of ubiquitous learning environments (also called “situatedness” [11]) allows sensing the situation of learners so that the learning system can provide adaptive support to the learners [10]. Ubiquitous devices and technologies can be used in order to seamlessly receive environmental data and provide personalized information related to the learner’s context. The context can be learner’s state, educational activity, environment state, system infrastructure etc. A ubiquitous learning environment can provide the means of student’s involvement even without student’s consciousness of the learning process.

Recently, researchers have developed u-learning environments for various applications. Researchers like Ogata [11], Jones & Jo [12], and Hwang et al. [10], among others, have proposed the attachment of RFID tags on surrounding objects. For example, when a student approaches an object, sensors detect his/her presence and transmit information about the object, which is received by the student’s handheld device. Then the student can scan or move the tagged objects following vocal or text instructions, or just answer questions concerning the identity of the objects. Zhao et al. [13] propose an adaptive content delivery framework for u-learning environment, which delivers contents adapted to learner’s interests and device features. Context awareness is integrated with the learning system to form an adaptive u-learning system, called AubiLearn. Sung [14] proposes the development of a u-learning environment, which seeks to enhance traditional learning by providing audio/video/chatting for asynchronous and on-going interaction. In the case of a synchronous mode in a ubiquitous classroom, students can move around u-space holding a mobile device and interact with the various embedded devices. In the case of an asynchronous mode, the system provides on-line testing services so that

students can take a test at any time from any place. Yang [15] has built a context-aware ubiquitous learning environment that can fully support the needs of peer-to-peer collaborative learning. A various set of computational and theoretical techniques have been developed during the last years in order to model the dynamics of systems with similar behaviors [16-30].

## 2. Innovations in Ubiquitous Computing Devices and Technologies

Although not designed primarily for educational use, modern mobile devices enable new possibilities for learning. They integrate old with new learning tools: book, paper, pencil, camera, video camera, radio, computer, and telephone, to support learning that is personal, contextualised, and controlled by the learner [31]. Therefore, ubiquitous devices have become integrated into education. Multiple network connections such as cellular, Wi-Fi, Bluetooth, and NFC, provide long-, medium-, or short-range wireless communication for different mobile devices.

Mobile devices used for u-learning include Personal Digital Assistants (PDAs), Tablet PCs and mobile phones. Many years ago, cell phones were used just for making calls, while PDAs were used as personal, portable organizers and tablets as viewers. In the following years PDAs gained cellular phone features, cell phones owned more PDA-like and PC-like features, while tablets transformed to Tablet PCs. Nowadays, rapid technological development has led to the absorption of functionality of one device into the new version of another device, making categorization of mobile devices inconvenient.

Contemporary mobile phones, or smartphones, have become truly pervasive and ubiquitous; they are accessible and can be reached around the world [2]. When iPhones went on sale five years ago, they were relatively expensive. By the arrival of Google's Android mobile software in late 2008, the finger-driven touchscreen experience was democratized, since smartphones were brought cheaper [32]. Smartphones are now characterized by powerful processors, multimedia capabilities (SMS/text, camera, video, TV, radio, alarm, mp3 audio, music composer), ample storage, e-mail, Web accessibility, cloud accessibility, tracking of locations and navigation capabilities [32]. A main barrier to the integration of smartphones in education is that up to now in most European countries and the US people have to pay extra to get internet data on their phone [32].

Pen computers have been available over 15 years ago. Around 1999, an emerging generation of WebPads started, which were pen tablets with wireless internet connection. At the end of 2002, Microsoft released a new WebPad, the Tablet PC, with a special version of Windows that use a stylus for navigation, digital ink and handwriting recognition. A smaller and cheaper tablet, the UltraMobile PC, was released in 2006. The iPad released by Apple Inc. in the spring of 2010 and many companies responded announcing Tablet PCs based on Google's Android OS. The "Handy-Ai" developed by Fujitsu, for example, is a tablet PC that incorporates both the use of the device as a traditional tablet (viewer) and as a PC supporting keyboard input; lately we witness development of novel ubiquitous devices equipped with various types of sensors, closely linked with cloud services [33]. Cloud computing has changed the role of ubiquitous devices, providing better usability than devices that perform data storage and processing locally. New technologies are developed to support cloud services. For example, "hypervision" creates virtual environments in a single physical device, enabling the separation of personal data from other confidential data when operating outside the cloud [33]. This technology would allow both educators and students to use a single mobile device either for personal use or in classroom.

Reading appliances, such as the Barnes & Noble Nook, introduced in 2009, are used for reading electronically books, newspapers and magazines that are published electronically [34]. Replacing hardcopy with digital education material can help reducing the cost of textbooks over a long term.

Interactive whiteboards are located to classrooms to enable lecturers to present multimedia lessons and write using electronic ink. Students find whiteboard enjoying and interesting, since they can easily interact and collaborate to solve a problem.

Teleconference meetings are taking place using today's technology, large screens, advanced computing techniques, and secure and confidential telecommunication [34]. Telepresences are used for distance learning, for example for collaborative master degree programs held in a country and coordinated by another country.

### 3. Ubiquitous Computing Devices and Technologies in Educational Environments

Several studies [35], [36], [37], have tried to explore the use of mobile devices in education. Koole [35], points out that m-learning is the intersection of three compounds: the device/technology aspect, the student's characteristics, and the social aspects. Crow et al. [36] conducted a study on the use of mobile devices in higher education using semi-structured interviews with three lecturers. They concluded that there are three criteria that are necessary for "switching gears" from e-learning to m-learning: instructor's awareness of opportunities, instructor's familiarity of new mobile devices and software applications, and institutional support and commitment. Recently, Renneberg et al. [37] studied the m-learning adoption in tablet devices instead of cell phones and PDAs. Tablets' screen size allows better visualization, enabling user interaction. Although tablets overcome the barriers of small screens, they still have limitations on storage capacity, input capabilities, and reliability. Lessons learned from teaching network application design to students using smartphones and cloud computing are reported in [38]. Students were motivated to learn independently, when they were free to develop their preferred mobile applications, and they collaborated to openly share code with each other. It seems that smartphone technology excites students about computing and networking.

Richards [39] attempts to merge the principles of universal design for learning with ubiquitous learning, in order to reduce the barriers for students with disabilities and learning difficulties. The first principle is to provide multiple means of representation. Ubiquitous learning provides learners the means to adapt contents according to their needs. The second principle is to provide multiple means of action and expression. This principle is fulfilled, for example, through the mobile use of social media where students can actively express themselves and interact with the leaning content. The third principle is to provide the means of engagement, which is fulfilled by all mobile applications in the instructional context. Social bookmarking sites, for example, allow students sharing their findings and adding a peer networking capability to the learning process.

In the following, we discuss the requirements captured by interviews with educators and students. We also outline the functional components of the integrated system along with a short description of their role and their interaction between each other through a representative use case.

#### 3.1. Interviews

Our pedagogical, m-learning and blended learning based teaching activities in Higher Education are part of a three years experiment in the Department of Informatics of the TEI of Athens aimed specifically at fulfilling the inclusion and support of students through mobile devices technology, and content delivery in the mainstream class and in parallel classes. Special emphasis was given to the inclusion of students with disabilities and learning difficulties. Twenty persons were participated in a voluntary basis. In particular, five instructors, a social worker, expert in Special Education, with good knowledge of the Sign Language, and fourteen (14) students (hearing notes' takers, deaf and hard of hearing students, and dyslexic students) worked in special parallel, "assistive", classes. The participating students also attended the same courses in the mainstream classes. Parallel classes were organized for the following courses: Databases I & II, Introduction to Programming (Pascal language), Programming (C language), Numerical Analysis and Introduction to Informatics.

Interviews with people and the experts in the program helped us to give proposals on the utilization of mobile devices and ubiquitous computing technology in the higher education classroom of the future. As a consequence, a new programme is funded in order to create the new integrated system for supporting students of the TEI of

Athens –mainly disabled students and students with learning difficulties- in the class and the laboratory using mobile technology and specialized software (e.g. text-to-speech).

We conducted semi-structured interviews to capture the experiences of the twenty (35) participants. Main findings of our research suggest the following interrelated directions of development for the integrated system of supporting the future classroom:

- E A student-centered, personalized, adaptive to the specific needs approach. It also means that there are not barriers in the inclusion and participation of all the students; the disabled students are supported; and there is not any obligation of physical presence in the classroom.
- E Fulfill the demand for resources, technical support and training to offer a basis for the understanding and adoption of the new technologies for instructional purposes.
- E Inclusion is related to the increased demand for interactivity, personalization and adaptation support, dissemination of information, and the Design 4 All approach.
- E Need of the academic community of the University to address the cultural change inherent in the use of new technologies of social networking. Forums, wikis, facebook, delivery of e-books could be incorporated to the integrated system and offer new possibilities in the framework of a blended learning approach e.g. the participation in collaborative schemes.

The classroom of the future will be based on the operation of Integrated Systems (IS) with a single logon, which include components that all are interrelated and interconnected. Main components of the IS will support all the forms of learning: classroom and online courses, ubiquitous learning environments based on ubiquitous technologies, m-Learning, blended-learning, before, during, and after the lesson. Content handling will be done online, and in real time. Other important components will be included in the IS: 1) for supporting the collaborative development of learning content, 2) to offer/gain access to multimedia information, 3) to personalize and adopt content according to the needs, and 4) to use Social media for informal learning, communication, encouragement of participation, etc. The IS will offer the possibility of various types of operation: student-centred, lecturer-centred, administrator-centred, and readers' view. A prerequisite for the effective use of the IS will be the generalized support of mobile devices, as well as interactive whiteboards and telepresence boards. The main functional components of the integrated system are the following:

- E Online real time component for supporting various types of teaching and learning: e-learning, m-learning, distance learning, blended learning, lessons in the mainstream class and in parallel classes
- E Personalization of learning and adoption according to the needs e.g. support of the design-4-all principles
- E Multimedia, collaborative learning content creation and delivery
- E Content quality control e.g. approval of new entries, handling of the material according to the preferences of students
- E Collaborative wikis and multimedia, collaborative dictionaries of terminology dynamically related and linked to the learning content
- E Social networking for the encouragement and support of the inclusion
- E Events based dissemination of information related to the academic life
- E Training of students, lecturers, technical and administrative staff
- E Help desk
- E Resources planning and allocation
- E Volunteers' database for supporting teaching and learning. Volunteers could be Note takers, Sign Language interpreters, readers for blind students, etc.
- E Authentication and encryption procedures

Authentication and encryption procedures are vital for the security of the integrated system. While the student sends a request from her/his mobile device to retrieve content from the requested resources that are not critical, only the permissions of the requester are evaluated against the local policy. In the case of critical requests, such as taking part to examinations, the server also identifies the learner's identity using public key encryption techniques.

### 3.2. *Use case*

In the following, we shall present and discuss the representative utilization scenario (use case) that describes the class of the future.

The lecturer and/or the teaching assistant(s) can use the integrated system to support online the lecture. They can upload the slides of the presentation and deliver multimedia educational material to the website of the learning environment. The system automatically creates dynamic links to the multimedia, collaborative, multilingual dictionary of terms and concepts.

Students can attend (online, real-time scheme is supported) the mainstream class or parallel, "assistive" classes. Alternatively, students can remotely attend classes from their own place. They can use mobile devices to focus on the lecturer, the assistant, or the Sign Language interpreter. They can access the educational material according to their specific needs, e.g. to see a previous slide or a whole lecture in order to answer in specific questions of the lecturer, to read various entries for a term in the dictionary, to see subtitles in a video, to hear the description of a diagram, to follow the dynamic links that exist in the slides and the accompanying educational material.

During the lecture, both lecturers and students use mobile devices to create and publish question and answers, new entries in the dictionary, new diagrams, text, and video. They can add comments, notes, and highlights. The disabled students, using their mobile devices can contribute to the collaborative content during the lesson or afterwards recording video in Sign Language, adding subtitles, or comments. They can use video, text to speech to add new content and criticize existing. Lecturers and teaching assistants can also send personal instructions, notifications, and schedule reminding messages to students' cell phones.

Finally, mobile devices are used for social networking, which supports the creation of student communities of interest, enables consultation and discussion, and disseminates information related to the events of the academic life, the cultural life, sports, entertainment, e.tc.

## 4. **Conclusions**

In the classroom of the future, educators should be up to date, employing latest devices and technologies in order to deliver knowledge according to student's lifestyle. The latter have changed radically, influenced by the wide spread of mobile devices. Ubiquitous learning environments, equipped with ubiquitous devices and exploiting ubiquitous technologies can encourage student's involvement in the learning process, without requiring student's active attention. U-learning can relate learning to the learner's situation and increase effectiveness and efficiency of education system. In this paper, we have exploited new possibilities for ubiquitous learning by examining also the features of modern portable devices. We have examined a use case scenario for a class in the future that will be able to provide facilities for remote teaching and also to support the student with additional material which will be available anytime and anywhere, using mobile devices. It is apparent that these features are not far from being widely used in the near future, as mobile devices gain in power and processing capabilities and as their price is becoming lower.

Trivelas and Dargenidou [40] underline that Higher Education Institutes' culture often lacks of external orientation and organisational adaptation. Creativity and innovativeness values are sacrificed in favour of



bureaucracy, revealing a crucial weakness of Institutes' culture profile. Furthermore, Institutes' culture suffers from low levels of market culture, a fact that is often interpreted as restrictive use of new innovative technologies for goal achievement, productivity, task accomplishment, planning and efficiency. In the near future, our research will focus on the examination of the influence of the organisational culture on the quality of services provided in higher education, and we shall try to combine the results with further studies based on strategies for improving the quality of learning process, and students' retention. Grounded in the theory of dynamic capabilities, a well established theory in the field of the firms' business strategy, our study will also focus on the conceptualization of a strategy for Higher Education Institutes in order to create and extend the IT competencies and eventually provide a competitive advantage [41]. The concept of dynamic capabilities can help us to understand how the Institute's resources (human, technological, economic, organizational) could evolve through time, offering competitive advantage [42].

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